System and Method for Analyzing Strategic Network Investments in Wireless Networks

RELATED APPLICATION DATA

This application claims priority to and the benefit of U.S. Provisional Application No. 60/534,658, filed on January 6, 2004, entitled "Systems and Methods for Making Strategic Capital Investments for Wireless Network," which application is hereby incorporated herein by reference.

5   TECHNICAL FIELD

The present invention relates generally to wireless networks and, more particularly, to systems and methods for analyzing strategic network investments in wireless networks.

BACKGROUND

The wireless telecommunications industry has been experiencing a tremendous growth in the past few
10   years and, as a result, is often characterized by fierce competition between wireless service providers. In an attempt to increase revenues and profits, it is generally important for the service providers to provide better services with lower costs. Because RF (Radio-Frequency) equipment (*e.g.*, transmission equipment, wireless network equipment) and operation cost is one of their largest network investments, it is generally important for wireless service providers to ensure that those investments increase returns in terms of revenue and profit.

15   Figure 1 illustrates a typical wireless telecommunication access (RF) network wherein base transceiver stations ("BTS"), such as BTS101 – BTS105, are deployed at certain locations. A BTS (also called a cell site) contains equipment such as a radio tower, antennas, radios, and cables for supporting the traffic in its coverage area. A BTS coverage area is typically divided into sectors, such as sectors C101 – C115, in which transceiver antennas face to a certain orientation for covering an area within an angle. In typical installations, each sector C101 – C115
20   covers an area within a 120° angle.

As their subscriber base grows, wireless service providers need to identify where in the network to invest in order to provide satisfactory services to subscribers. For example, service providers need to identify BTSs and/or sectors of BTSs that require more equipment to support the current or projected traffic in each area or, in another example, need to identify where an additional BTS should be located for sufficient traffic coverage.

25   Current planning systems and methods attempt to create network plans that minimize the overall cost while maintaining coverage of a certain percentage of total traffic (Erlangs) in the network. These systems and methods, however, fail to account for the different level of revenue contributions from different groups of subscribers. As a

result, current planning systems and methods may generate network plans that suggest investment in areas that will not generate the most revenue or profit for the wireless service provider. In fact, the current planning systems and methods may indicate an investment in a location that will not generate any additional revenue, creating an investment and operational loss for the service provider.

5   For example, reference numerals E101-115 indicate the uncovered Erlangs for sectors C101-115, respectively. In current planning systems, the sectors are prioritized based on the uncovered traffic in each sector (E101 – E115) and the investment (*e.g.*, radios) in a sector depends on the priority of that sector. Additional BTSs may be deployed first at the locations where uncovered Erlangs are the highest, regardless of the amount of revenue (or loss) the investment is expected to return.

10   SUMMARY OF THE INVENTION

       These and other problems are generally reduced, solved or circumvented, and technical advantages are generally achieved, by embodiments of the present invention, which provides systems and methods for analyzing strategic capital investments in wireless networks.

       Embodiments of the present invention provide a measurement-based system and method to assist wireless

15. service providers in analyzing strategic capital investment decisions in their networks in order to increase revenue and profitability. Embodiments prioritize the geographical areas and BTSs for capital investments based on the profitability of the areas and sites. The profitability of a geographical area or a cell site may be calculated based on network Operation Measurements and subscriber CDR (Call Detail Record) data. The system and method can be used by service providers to reduce network churn by understanding where dissatisfied subscribers experience poor

20 service and where network investments need to be made to improve the services and reduce churn.

       It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures or processes for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

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BRIEF DESCRIPTION OF THE DRAWINGS

The object and other advantages of this invention are best described in the preferred embodiment with reference to the attached drawings that include:

Figure 1 is a network diagram of a wireless cellular network;

5   Figure 2 is a network diagram illustrating an embodiment of the present invention;

Figure 3 is a flow chart illustrating a method of analyzing strategic network investments in wireless networks in accordance with an embodiment of the present invention;

Figure 4 is a flow chart illustrating a method of computing the Subscriber Profit Proxy (SPP) for subscribers in wireless networks in accordance with an embodiment of the present invention;

10   Figure 5 is an illustration of the fields of interest in a CDR (Call Detail Record) sample in accordance with an embodiment of the present invention;

Figure 6 is a flow chart for a method of calculating the Investment Return Value for all sectors in wireless networks in accordance with an embodiment of the present invention;

Figure 7 is a network diagram illustrating a method of analyzing network investments for additional BTSs

15   in wireless networks in accordance with an embodiment of the present invention;

Figure 8 is a flow chart illustrating a method of analyzing capital investments for additional BTSs in wireless networks in accordance with an embodiment of the present invention;

Figure 9 is a flow chart illustrating a method for identifying coverage holes in a wireless network in accordance with an embodiment of the present invention;

20   Figure 10 is a network diagram illustrating a method of analyzing BTS-decommission decisions when merging multiple wireless networks in accordance with an embodiment of the present invention; and

Figure 11 is a flow diagram illustrating a method of analyzing BTS-decommission decisions when merging multiple wireless networks in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The making and using of the presently preferred embodiments are discussed in detail below. It should be appreciated, however, that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed are merely illustrative of specific ways
5   to make and use the invention, and do not limit the scope of the invention.

One skilled in the art will appreciate that embodiments of the present invention may be used by wireless service providers to increase gross profit margins as opposed to the typical method of maximizing traffic coverage using Erlangs. Embodiments of the present invention prioritize geographical areas and BTSs for network investments based on the profit loss of the areas and sites. Network investments may be based upon, for example,
10   call detail records and operation measurements.

Embodiments of the present invention may also be utilized to reduce subscriber churn rates. For example, when targeting subscribers at the end of their contracts, the system and method described herein may reduce churn by providing a list of investment areas where targeted subscriber service experiences need the most improvement.

Figure 2 is a network diagram illustrating a system and method of analyzing strategic network
15   investments in wireless networking in accordance with an embodiment of the present invention. Generally, investment return in terms of dollars is calculated for each sector based upon, among other things, the profit loss due to uncovered traffic and investment (e.g., radios) cost to recover the uncovered traffic. In Figure 2, R201 – R215 represent the investment return in terms of dollars due to uncovered traffic for sectors C201 – C215, respectively. As will be described in greater detail below, after the investment return is determined for each sector, the sectors
20   may be prioritized based on investment returns that the service provider may expect from an investment in each sector. In this manner, the service provider is able to make the investment decision in a sector based upon the amount of investment return expected, thereby increasing the returns on investment dollars and profit.

Figure 3 is a flow chart of a method of investment decisions based upon expected investment returns in wireless access networks in accordance with an embodiment of the present invention. The method begins in step
25   301, wherein Subscriber Profit Proxy (SPP) is created for one or more subscribers in the network. Generally, the SPP value quantifies the amount of profit (gross earnings) the service provider expects to receive from a given subscriber over a specified period of time. A method of determining the SPP value of one or more subscribers is discussed in greater detail below with reference to Figure 4.

It should be noted that the subscribers selected for analysis may be a particular group, all of the subscribers
30   in a network, or the like. For example, to determine an investment strategy for data services, the group of subscribers may consist of those subscribers currently using the data services being analyzed. Another example includes specifying a group of subscribers whose subscription contracts will end shortly (e.g., in a month, next quarter, or the like) in order to reduce churn by investing in networks to improve the service quality for that group of subscribers.

In step 302, the Minutes-of-Use (MOU) is determined for each subscriber. The MOU may be determined, for example, from Call Detail Records (CDRs). In a preferred embodiment, the MOU for each subscriber is determined for the peak usage hours. In this manner, only the "revenue generating" periods are taken into account for the investment decision. For example, many service providers provide free service during nights and weekends.

5   Use during this time, therefore, is not considered as generating revenue, and when determining where an investment should be made to increase revenue and profit, should not be considered.

It should be noted that peak usage hours are typically defined by wireless service providers and may vary between regions, demographics, and plan details. Additionally, the duration of the peak usage period may also vary. For example, the peak usage period over which MOU may be determined may be a month, a week, or a weekday of

10   peak usage hours, and may be dependent upon, among other things, the computational power of the computational system. A longer peak usage period provides more precise results, but may require more computational power.

Next, in step 303, a service quality metric for each sector in the network is determined. In a preferred embodiment, step 303 collects the service quality metric, such as a drop-call rate, for each sector in the network. Drop-call rate D_k at sector k may be calculated by aggregating all calls terminated abnormally in each sector as

15   determined by the call termination cause field 504 (discussed below with reference to Figure 5) in the CDRs. The drop-call rate at each sector may also be collected from the Operational Measurements (OMs) at the BTSs and/or BSCs (Base Station Controllers).

In step 304, investment returns for each sector based at least in part on the SPP values, MOU, and service quality metric data are calculated. A method that may be used to determine the investment return for each sector is

20   described in greater detail below with reference to Figure 6.

In step 305, a capital investment strategy is created by prioritizing the sectors in the network. Sectors with higher Sector Investment Returns should be given higher priorities to invest. Other factors, however, may also factor into the investment decision.

Figure 4 is a flow chart illustrating a method of the SPP for one or more subscribers discussed above with

25   reference to step 301 of Figure 3 in accordance with an embodiment of the present invention. It should be noted that in a preferred embodiment, the SPP calculations are calculated as long-term profit values. Other time periods (shorter or longer) may be used. The equations given herein are provided as examples and, accordingly, may be altered to customize the equations for a given scenario.

The process begins in step 401, wherein a subscriber i is selected. In step 402, the revenue generated by the

30   subscriber i per month is calculated from the service provider's database. Thereafter, the expected number of months that the subscriber would stay under the current contract is determined in step 403, the acquisition cost (*e.g.*, marketing cost, discount on mobile terminals, etc.) to the service provider for signing the subscriber is determined in step 404, and the cost of delivering services to the subscriber is determined in step 405. The expected number of months that a subscriber would stay under a particular contract is usually the same for a category of subscribers

35   under the same contract and may be calculated based on the number of months of stay for all previous and existing subscribers.

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The SPP of subscriber i may be calculated using the formula presented in step 406.

$$SPP_i = V_i * M_i - A_i - S_i$$

wherein

V_i is the revenue per month for subscriber i;

M_i is the expected months under contract for subscriber i;

A_i is the acquisition cost for subscriber i; and

S_i is the service delivery cost for subscriber i.

After computing the SPP value for subscriber i, processing returns to step 401 to compute the SPP value for the next subscriber in the network. This process may be repeated until a SPP value has been determined for all subscribers in the network.

Figure 5 illustrates fields of a Call Detail Record (CDR) that may be used in an embodiment of the present invention. In particular, Figure 5 illustrates fields of a CDR that may be collected in step 302 of Figure 3 to determine peak usage periods. Field 501 in Figure 5 indicates the call type which is, in this example, a "Mobile Terminated" call (i.e., a call terminating at a mobile unit). Fields 502 provide identities of subscribers (calling and called parties). Fields 503 show the start and end time of the call. Field 504 illustrates the call termination cause, which is "Normal Release" in the illustrated example. Any abnormal release in this field typically indicates a dropped call. Field 505 gives the call duration in seconds. Field 506 provides the sector ID where the call takes place. If a subscriber travels among multiple sectors during a call, the IDs of all sectors where the subscriber travels and the duration of the call in each sector will be recorded in the CDR.

Figure 6 is a data flow diagram that may be used to determine the investment return per sector as described above in step 304 of Figure 3 in accordance with an embodiment of the present invention. In particular, after performing step 303 in Figure 3, processing may proceed to step 601 of Figure 6, and after completing the processing described in Figure 6, processing may return to step 305 of Figure 3.

The process begins in step 601, wherein a sector is selected. In step 602, the Sector Profit P_k is calculated for the selected sector. The Sector Profit P_k may be calculated based upon the Minutes-Of-Use (MOUs) for all subscribers in each sector, which may be determined by aggregating all of the call minutes for all subscribers within the selected sector as may be determined from fields 505 ("Call Duration") and 506 ("CellIdentity") of the CDR illustrated in Figure 5. Sector Profit P_k may be computed using the following formula, which is based on the MOU and SPP of the subscriber.

$$P_k = \sum_i \left[SPP_i * \frac{MOU_{ik}}{\sum_j MOU_{ij}} \right]$$

wherein

k represents a sector;

i represents a subscriber;

j represents a sector;

P_k is the profit for sector k;

SPP_i is the SPP value for subscriber i;

MOU_{ik} is the minutes of use for subscriber i in sector k;

MOU_{ij} is the minutes of use for subscriber i in sector j; and

$\Sigma_j MOU_{ij}$ is the sum of the minutes of use for subscriber i in all sectors.

Thereafter, a Sector Investment Return R_k may be calculated in step 603 based on Sector Profit Loss, which is equal to $P_k \times D_k$ (P_k is Sector Profit and D_k is drop-call rate) less the investment needed to recover the drop calls at the sector. The equation for calculating the Sector Investment Return R_k may be expressed as follows.

$$R_k = P_k + D_k - I_k$$

wherein

k represents a sector;

P_k is the profit for sector k;

D_k is the drop-call rate for sector k; and

I_k is the investment needed to recover the drop calls in sector k.

After calculating the Sector Investment Return of sector k in step 603, the process proceeds to step 604 to determine if additional sectors need to be processed. The process returns to step 601 to determine the Sector Investment Return for the next sector.

Figure 7 is a network diagram illustrating the concept of determining where additional BTS investments may be made in uncovered areas to increase return on investment in accordance with an embodiment of the present invention. Uncovered areas (referred to as "Coverage Holes") H701 and H702 represent areas in which the current network topology fails to sufficiently cover. As a result, the coverage holes represent lost revenue for wireless service providers who constantly deploy new BTSs to fill the "coverage holes" in order to recover the revenue loss and improve subscriber satisfactions. The following paragraphs disclose a system and method for evaluating the coverage holes to determine new BTS locations to increase revenue and profit. Generally, the teachings of the

present invention determine investment returns (*e.g.*, investment returns R701 and R702 for coverage holes H701 and H702, respectively) and prioritize the investment returns to determine the profitable locations for a new BTS.

Figure 8 is a data flow chart for identifying additional BTS locations for network investment in accordance with an embodiment of the present invention. The process begins in step 801, wherein the "coverage holes" in the
5   network are identified using sector orientations, time-advance data, mobile location data, dropped-call data from CDRs, and drive-test data (Figure 9 will describe coverage hole identification in greater detail). At step 802, the revenue loss U_k at coverage hole k is determined using, for example, the revenue data and CDR at the BTS for all BTS in the network. The following equation may be used to determine the revenue loss U_k

$$U_k = \Sigma_i \left[D_{ik} * AMOU_i * UPM_i \right]$$

10   wherein

k represents a coverage hole;

i represents a subscriber;

D_{ik} is the number of monthly dropped calls by subscriber i at coverage hole k;

$AMOU_i$ is the average MOU per call of subscriber i;

15   UPM_i is the revenue generated per minute by subscriber i; and

U_k is the revenue loss at coverage hole k.

D_{ik}, $AMOU_i$ and UPM_i can be obtained from CDR data. In step 803, the cost for adding new BTSs to cover coverage-hole k is determined. The cost for BTSs to cover coverage-hole k (C_k) may include, for example, monthly equipment cost E_k, site monthly leasing cost L_k, and monthly transport leasing cost T_k. Other monthly costs O_k,
20   such as electricity, may also be included in C_k. The BTS costs preferably include costs for multiple BTSs, if multiple BTSs are required.

In step 804, the BTS investment return value R_k is determined for each coverage hole. In a preferred embodiment, the investment return value R_k is determined by the revenue loss due to coverage-hole k (U_k) less the cost of the additional BTS required to cover the coverage hole (C_k). Thereafter, in step 805, a BTS investment
25   strategy may be determined at least in part by prioritizing the BTSs based on their investment return values R_k for the BTSs.

Figure 9 is a flow diagram that shows a method for identifying the coverage holes in the network as described above in step 801 of Figure 8 in accordance with an embodiment of the present invention. In particular, after initiating the process at step 800 in Figure 8, processing may proceed to step 901 of Figure 9, and after
30   completing the processing described in Figure 9, processing may return to step 802 of Figure 8.

In step 901, a dropped call l is selected and the sector k is determined where the dropped call was recorded based on CDR data. In step 902, a determination is made whether or not the dropped call mobile is GPS (Global Position System) capable. If a determination is made that the dropped call mobile is GPS capable, then processing proceeds to step 904, wherein the location record of the dropped call can be found from the subscriber's CDR data. Otherwise, processing proceeds to step 903, wherein the dropped call location DCL_l is determined. The dropped call location DCL_l may be determined using the following formula.

$$\overrightarrow{DCL_l} = \overrightarrow{SL_k} + TA_l * \begin{pmatrix} \overrightarrow{\cos(\alpha_k)} \\ \sin(\alpha_k) \end{pmatrix}$$

wherein

l represents a dropped call;

k represents a sector;

SL_k is the location of the sector k;

α_k is the orientation of the sector k; and

TA_l is the time advance of the dropped call mobile, which indicates the distance between the dropped call mobile and the sector k.

Next, in step 904, the location of the dropped call l is recorded. In step 905, a determination is made whether or not additional dropped calls have occurred whose location has not been determined. If such a dropped call exists, processing returns to step 901 to determine the location of the next dropped call. Otherwise, processing proceeds to step 906, wherein a drive test is preferably performed to identify the coverage holes in the network using the dropped call locations. At a particular dropped call location, there may be multiple dropped calls that occurred. The dropped call locations may be prioritized for drive test based upon the number of dropped calls at each location. Generally, a drive test involves RF engineers driving through the identified locations to measure the RF signal strength to more precisely determine the coverage holes.

Figure 10 is a network diagram that illustrates a BTS decommissioning strategy in accordance with an embodiment of the present invention. One example of a situation in which a BTS may need to be decommissioned is when wireless service providers merge. In many cases, wireless service providers may have overlapping network components. Thus, when wireless service providers merge, the merged network may contain redundant network elements. In these cases, it may be desirable to decommission some BTSs in the network to save operational costs and improve network performance (*e.g.*, by reducing RF interference).

Generally, an embodiment of the present invention determines a BTS decommissioning strategy by determining a BTS Investment Return Value (R901 – R907) for each BTS based on the revenue loss of

decommissioning the BTS and cost of keeping the BTS. The method is described in greater detail below with reference to Figure 11.

Figure 11 is a data flow diagram that illustrates a method for analyzing a BTS decommissioning strategy in accordance with an embodiment of the present invention. The process begins in step 1101, wherein the revenue loss U_k from BTS k if BTS k were to be decommissioned is calculated. The revenues loss U_k is preferably based upon the revenue data and CDR data at BTS k. The following equation may be used to determine the revenue loss U_k if BTS k were to be decommissioned.

$$U_k = \Sigma_i \left[V_i * \frac{MOU_{ik}}{\Sigma_j MOU_{ij}} \right]$$

wherein

k represents a BTS;

i represents a subscriber;

V_i is the revenue per month for subscriber i (as determined at step 402 of Figure 4);

MOU_{ik} is the MOU of subscriber i at BTS k (as determined at step 602 of Figure 6);

MOU_{ij} is the minutes of use for subscriber i in sector j; and .

$\Sigma_j MOU_{ij}$ is the sum of the minutes of use for subscriber i in all sectors.

The calls that are expected to be processed by neighboring BTSs are calculated by the covering areas of the neighboring BTSs and the spare capacity at those BTSs. In step 1102, the cost C_k of maintaining the BTS k is determined, preferably as the sum of the monthly equipment cost E_k, site monthly leasing cost L_k, and monthly transport leasing cost T_k. Other monthly costs O_k, such as electricity, may also be included. Next, in step 1103, a BTS decommissioning return value R_k for BTS k is determined, preferably as the cost C_k of maintaining BTS k less the revenue loss U_k from BTS k if BTS k were to be decommissioned. A return value R_k may be calculated for a plurality of BTSs. Thereafter, in step 1104, a BTS decommissioning strategy may be determined based at least in part by prioritizing the BTS decommissioning return values R_k for each BTS k.

Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present invention, processes, machines, manufacture, compositions of matter, means, methods, or

steps, presently existing or later to be developed, that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present invention. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.